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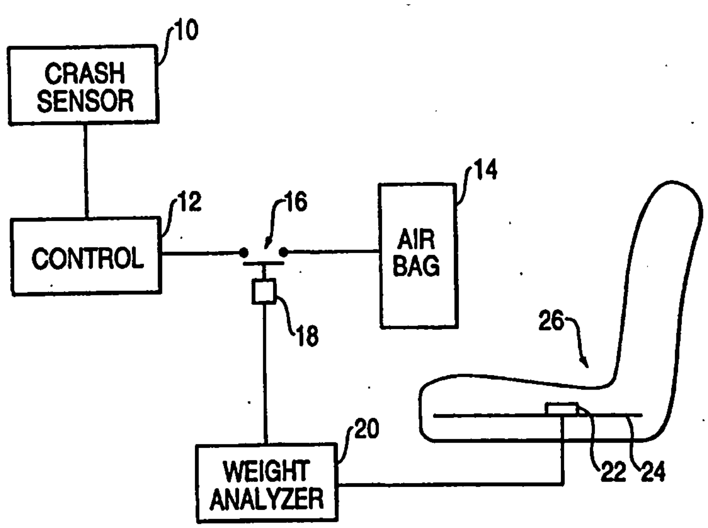
(54) Title: WEIGHT SENSOR FOR CONTROLLING AIRBAG DEPLOYMENT



(57) Abstract

An arrangement is provided for controlling activation of an airbag system (10, 12, 14) in a vehicle. The vehicle has a passenger seat (26) comprising a seat frame (32) and a string network (24) attached to the seat frame for supporting a weight of an occupant in the passenger seat. The arrangement comprises a sensor (22) operatively coupled to a portion of the string network for sensing a tensile load exerted on the string network created by the weight of the occupant in the passenger seat and producing an output signal representing the tensile load. A processing unit (20) is coupled to the output of the sensor for producing a control signal for controlling activation of the airbag system when the signal representing tensile load reaches a pretermined threshold value.

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WEIGHT SENSOR FOR CONTROLLING AIRBAG DEPLOYMENT

BACKGROUND OF THE INVENTION

The present invention relates to a control system for airbag deployment in an automotive vehicle in the event of a crash, and more particularly to a system for controlling airbag deployment in an automotive vehicle in dependence of the weight of an occupant, and even more particularly to a weight sensor for use in such a control system.

Airbags are widely used in automotive vehicles to protect front-seat occupants during a crash event. When activated, the airbags are designed to inflate at a speed of up to 200 miles per hour. An airbag inflating at this high rate can impart a severe blow to an occupant. The impact can be fatal if the occupant is an infant, child or small adult. Recent fatalities of infants and small children as well as adults caused by deploying airbags have exposed a grave fault in current airbag technology. There is an urgent need to find a remedy to this problem to minimize, if not totally prevent, such further fatalities and to ensure maximum safety for children and small adults.

One concept widely considered in the automotive industry to correct the problem is development of a smart airbag system that disables the airbag when an infant, child or small adult is riding in the front seat. The key to implementing this concept is to identify whether the front-seat occupant requires airbag deactivation. A simple way to identify (or classify) the occupant is based on weight. Active research and development efforts are ongoing in the automotive industry for developing reliable and inexpensive weight sensors for application to a smart airbag system. Most of the weight sensors that have been developed to date have been either overly complicated and/or uneconomical to install.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a reliable and inexpensive weight sensor for use in controlling airbag deployment in an automobile.

It is a further object of the invention to provide such a weight sensor which is economical to install into the seat of an automobile.

The above and other objects are accomplished in accordance with the invention by the provision of an arrangement for controlling activation of an airbag system in a vehicle including a passenger seat comprising a seat frame and a string network attached to the seat's frame for supporting the weight of an occupant in the passenger seat, the arrangement comprising: a sensor operatively coupled to a portion of the string network for sensing a tensile load exerted on the string network created by the weight of the occupant in the passenger seat and having an output for producing an output signal representing the tensile load; and a processor coupled to the output of the sensor for producing a control signal for controlling activation of the airbag system when the signal representing the tensile load reaches a pre-determined threshold value.

In one embodiment of the invention, a string in the string network has a magnetic characteristic that changes as a function of tensile load on the string and the sensor comprises a magnetic sensor for sensing the magnetic characteristic.

According to a further aspect of the invention, the sensor may comprise a ferrite core, an excitation coil wrapped on a portion of the ferrite core and a detection coil wrapped on a second portion of the ferrite core and having leads for producing an output signal that varies with changes in the magnetic characteristic when the excitation coil is excited with a current. In this embodiment, the sensor is mounted on or near one of the strings of the string network.

According to another aspect of the invention, the excitation coil and detection coils may be wrapped directly on one of the strings of the string network. In this case, the string with the

excitation coil and detection coil wrapped thereon may comprise a prefabricated unit which can be installed by the seat manufacturer or at a later point in time as an additional string in the string network that supports the occupant of the seat.

According to a further embodiment of the invention, the string network includes first and second rods each connected to the seat frame by springs, with the rods connected to each other by strings. The sensor comprises a spring-length-change sensor operatively coupled to one of the springs for producing an output signal representing a change in length of one of the springs, which change of length is proportional to the tensile load exerted on the string network. In this embodiment of the invention the sensor may comprise a Hall-effect device which is attached to one end of the spring and a magnet attached to the other end of the spring, whereby relative movement between the magnet and the Hall-effect device results in an output from the Hall-effect device that is proportional to the change in length of the spring which in turn is proportional to the tensile load on the string network. Alternatively, other types of change-of-length sensors may be used to implement this embodiment of the invention.

The invention thus provides an inexpensive, durable as well as rugged weight sensor which can be used for sensing the tensile loading effect on an automobile seat created by an occupant of the seat. The tensile loading effect can be correlated with occupant weight using a preestablished relationship or calibration. In accordance with the invention, the weight of the occupant is then compared with a predetermined threshold in such a manner that the airbag remains disabled until the weight of the occupant exceeds the threshold. In this manner, infants, children and small adults are protected against the impact of a high inflation rate airbag.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block circuit diagram of an airbag inflation control system implemented

with a weight sensor according to the invention.

Figure 2 is a plan view of a typical string network fastened to a seat frame for use with the invention.

Figure 3 is a schematic block diagram of electronics and sensor for measuring tensile loading effects on a string according to one embodiment of the invention.

Figure 4 is a diagram showing examples of the relationship of stress with respect to normalized third harmonic amplitudes of the detection signal of the sensor in Figure 3 for different materials.

Figure 5 illustrates a side view in partial section of a modified sensor according to a further embodiment of the invention.

Figure 6 is a side elevation in partial section of a sensor according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1 there is shown an overall control system for controlling activation of an airbag in an automobile as a function of the output of a weight sensor in accordance with the invention. As shown, a crash sensor 10, which may be an accelerometer or other well known impact sensing device, has its output coupled to a control 12 which controls deployment of an airbag 14. The operation of crash sensor 10, control 12 and airbag 14 are well known in the art and need not be described in any greater detail. The connection between control 12 and airbag 14 is interrupted by a switch 16 controlled by a solenoid 18 which is responsive to the output of a weight analyzer or processor 20. In accordance with the invention, a weight sensor 22 is operatively associated with a string network 24 of a conventional automobile seat 26. As will be explained in further detail below, weight sensor 22 directly senses the tensile loading on

string network 24. Weight sensor 22 produces a signal representing the tensile loading effect on string network 24 which is fed to weight analyzer 20 which relates the signal to the weight of an occupant in accordance with a pre-established calibration curve, or a look-up table. Additionally, weight analyzer 20 compares the measured weight to a predetermined threshold and issues an output when the weight exceeds the threshold for causing solenoid 18 to close switch 16. Thus, the airbag is enabled when the weight of an occupant exceeds the threshold and disabled when the weight of the occupant is less than the threshold.

Figure 2 illustrates the string network in more detail. As shown, string network 24 comprises spaced-apart parallel rods 28a and 28b which are connected together by strings 30. Each of the rods is in turn connected to a seat frame 32 by a plurality of springs 34. A cushion (not shown) is supported by string network 24 so that when an occupant is seated on seat 26 (Figure 1) the weight of the occupant is transferred through the cushion to the string network which places strings 30 and springs 34 in tension.

In a conventional automobile seat, the strings of the string network are typically made of ferromagnetic steel wire. A tensile load applied to the ferromagnetic wire alters the magnetic characteristics, including, for example, the magnetic hysteresis and permeability of the material, and Barkhausen noise. Such magnetic characteristics can be measured with an appropriate sensor in accordance with the invention. The type of sensor will depend upon the particular magnetic characteristic that is to be measured and the chosen method of sensing.

Figure 3 illustrates a schematic block diagram of a magnetic sensor and electronics for measuring the tensile load effects on a ferromagnetic wire using a non-linear harmonic method. As shown in Figure 3, a sensor 40 comprises a U-shaped ferrite core having one leg 41a wrapped with an excitation coil 42 and another leg 41b wrapped with a detection coil 44. Excitation coil 42 is excited by an alternating current from a power supply 46. When sensor 40

is placed on or near one of the ferromagnetic strings 30 of string network 24, detection coil 44 will produce an output signal which is a function of changes in the magnetic characteristics of string 30. The signal output of the detection coil is fed to weight analyzer 20 which includes an amplifier 20a, a filter 20b and a processor 20c connected in series as shown.

In the operation of the circuit block diagram illustrated in Figure 3, an alternating excitation current is generated by power supply 46 for applying an alternating magnetic field to magnetic wire string 30. Detection coil 44 detects the magnetic response of ferromagnetic wire string 30, which changes as a function of the tensile load on the string network. The detected signal is amplified by amplifier 20a and filter 20b passes the non-linear harmonic components, typically the third harmonic of the applied field frequency. Non-linear harmonics are produced because of the magnetic hysteresis and non-linear magnetic permeability of the material of the ferromagnetic wire. The tensile load applied to the wire alters the magnetic hysteresis and permeability of the material, thus influencing the non-linear harmonic (NLH) amplitude. Examples of the effect of tensile load on NLH amplitude in wire materials are shown in Figure 4, wherein material No. 1 is an annealed nickel having a yield strength of about 30 ksi, material No. 2 is a temper-hardened nickel having a yield strength of about 135 ksi and material No. 3 is a steel wire having a minimum breaking strength of about 250 ksi. As shown, the NLH amplitude typically decreases approximately linearly with increasing tensile load, while the sensitivity to load (i.e., the amount of NLH amplitude change per unit tensile load) varies widely, depending on wire material. The processor determines the amplitude of the non-linear harmonic and correlates this amplitude with a pre-established calibration curve or utilizes a look-up table to determine the weight of the occupant. The weight of the occupant is compared with a threshold value and processor 20c outputs a signal if the threshold value is exceeded for activating solenoid 18 which closes switch 16 for enabling the airbag system in the manner

discussed in connection with Figure 1, so that, in the event of a crash event, the airbag will be deployed via control 12 in response to a signal from crash sensor 10.

In a modification of the embodiment illustrated in Figure 3, a magnetic sensor based upon the non-linear harmonic method discussed above could be comprised of excitation and detection coils wound directly on a string, omitting the ferrite core. To implement such a sensor economically, the sensor could be installed during fabrication of the string network at a seat manufacturer's plant by slipping the sensor comprising the excitation and detection coils over the string. Another approach is to make the sensor string assembly separately as shown in Figure 5 and to fasten this assembly as a prefabricated unit to the string network to serve as one of or an additional string in the string network. This latter embodiment need not involve the seat manufacturer. Furthermore, the wire in the assembly can be chosen to provide better sensitivity and resolution in weight sensing. Therefore, the prefabricated assembly is a preferred implementation according to this aspect of the invention.

As shown in Figure 5, the sensor string assembly according to this aspect of the invention includes a wire string 80 of chosen magnetic characteristics, having hooks 81 at each end, and a concentrically disposed magnetic sensor 82 comprised of an inner detection coil layer 84 and an outer excitation coil layer 86 would on a bobbin (not shown) made of a non-conducting material such as plastic. String 80 is slipped through a hole along a cylindrical axis of the bobbin (not shown) and is fixed to the parallel rods of the string network, for example rods 28a, 28b of the string network shown in Figure 2, by crimping the hooks 81 around the rods using an appropriate tool. The total length of the string, including the hooks, should be the same as the length of the existing strings in the seat (see, for example, strings 30 in Figure 2). The string material of the prefabricated sensor should be chosen so that its thermal expansion coefficient is about the same as that of the existing strings in the seat and its magnetic response

to tension is suitable for the intended weight sensing.

Figure 6 illustrates another embodiment of the invention which employs a change-of-length sensor for sensing a change of length of one of the springs of the string network. When an occupant is sitting on the seat, for example as shown in Figure 1, the springs of the string network illustrated in Figure 2 will be stretched in proportion to the weight of the occupant. By measuring the change in spring length, occupant weight can be determined. As shown in Figure 6, the change-of-length sensor includes a housing 50 having an interior space 51 in which there is disposed a Hall-effect device 52. Housing 50 is anchored to one end 34a of spring 34 by a connecting component 54 which has a curved leg 56 shaped to hook around a turn of spring 24 at end 34a. Also disposed within interior space 51 is a permanent magnet 58 attached to an end of a rod 60 having an opposite end attached to a connecting component 62 via a flange 64. Connecting component 62 is slidably disposed in an opening 66 of housing 50. Connecting element 62 has a curved leg 68 which is shaped to hook around an end turn of spring 34 at an opposite end 34b. A return spring 69 surrounds connecting element would 62 between flange 64 and an inner wall 70 of space 51 within housing 50. It may be appreciated that when spring 34 stretches, Hall-effect device 52 and permanent magnet 58 have an axial movement relative to one another because connecting element 62 is allowed to slide through opening 66 in an axial direction of the housing. Return spring 69 has a smaller spring force than spring 34 of the spring network so as not to impact in a significant way the stretching of spring 34, but at the same time to insure that permanent magnet 58 returns to a nominal position relative to Hall-effect device 52 in the unstretched condition of spring 34. Hall-effect device 52 produces a voltage output in a known manner which will vary as a function of the stretching of spring 34 which in turn corresponds to the tensile load on the string network. The output of Hall-effect device 52 would then be fed to a weight analyzer and correlated with the weight of an occupant as discussed

previously for controlling activation of the airbag system.

It may be appreciated that other types of linear displacement sensors may be utilized to measure the change in length of the spring according to this aspect of the invention. For example, the Hall-sensor and magnet arrangement of Figure 6 could be replaced with a potentiometer (for example conductive plastic and contactless potentiometers manufactured by Midori American Corp.), or a linear variable differential transformer (for example, DVRT manufactured by MicroStrain).

The invention has been described in detail with respect to preferred embodiments, and it will now be apparent from the foregoing to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and the invention, therefore, as defined in the appended claims is intended to cover all such changes and modifications as fall within the true spirit of the invention.

WHAT IS CLAIMED IS:

1. An arrangement for controlling activation of an airbag system in a vehicle including a passenger seat comprising a seat frame and a string network attached to the seat frame for supporting a weight of an occupant in the passenger seat, the arrangement comprising:

a sensor operatively coupled to a portion of the string network for sensing a tensile load exerted on the string network created by the weight of the occupant in the passenger seat and having an output for producing an output signal representing the tensile load; and

means coupled to the output of the sensor for producing a control signal for controlling activation of the airbag system when the signal representing tensile load reaches a predetermined threshold value.

2. The arrangement according to claim 1, wherein the string network includes a string comprised of a ferromagnetic wire having a magnetic characteristic that changes as a function of tensile load on the wire, and the sensor comprises a magnetic sensor for sensing the magnetic characteristic.

3. The arrangement according to claim 2, wherein the sensor comprises a ferrite core, an excitation coil wrapped on a first portion of the ferrite core and adapted for being supplied with an excitation current, and a detection coil wrapped on a second portion of the ferrite core and having output leads for producing the output signal; and the sensor is mounted adjacent one of the strings of the string network.

4. The arrangement according to claim 2, wherein the sensor comprises an excitation coil wrapped on one of the strings of the string network and adapted for being supplied with an excitation current and a detection coil wrapped on the one string and having output leads for producing the output signal.

5. The arrangement according to claim 4, wherein the one string with the excitation coil and detection coil wrapped thereon comprises a prefabricated unit.

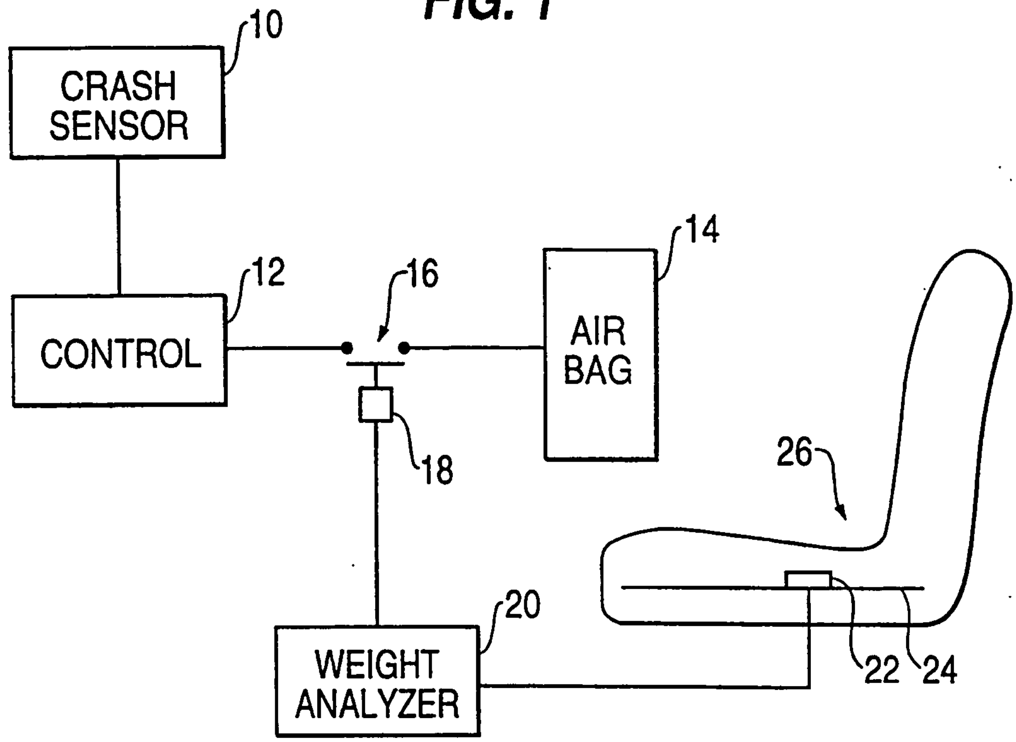
6. The arrangment according to claim 4, wherein the excitation coil surrounds the detection coil.

7. The arrangement according to claim 1, wherein the string network includes first and second rods spaced apart from one another, strings connecting the rods together and springs connecting the rods to the seat frame; and the sensor comprises a spring-length-change sensor operatively coupled to one of the springs for producing an output signal representing a change in a length of the one spring, the change of length being proportional to the tensile load exerted on the string network.

8. The arrangement according to claim 7, wherein the sensor comprises a Hall-effect device attached to one end of the one spring and a magnet disposed adjacent the Hall-effect device and attached to another end of the one spring so that the magnet and Hall-effect device move relative to one another when the one spring is stretched due to the weight of the occupant on the seat.

9. The arrangement according to claim 7, wherein the sensor further includes a spring mounted for biasing one of the magnet and Hall-effect device into a predetermined position relative to one another in the absence of the weight of the occupant.

FIG. 1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CONTROL
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AIR BAG
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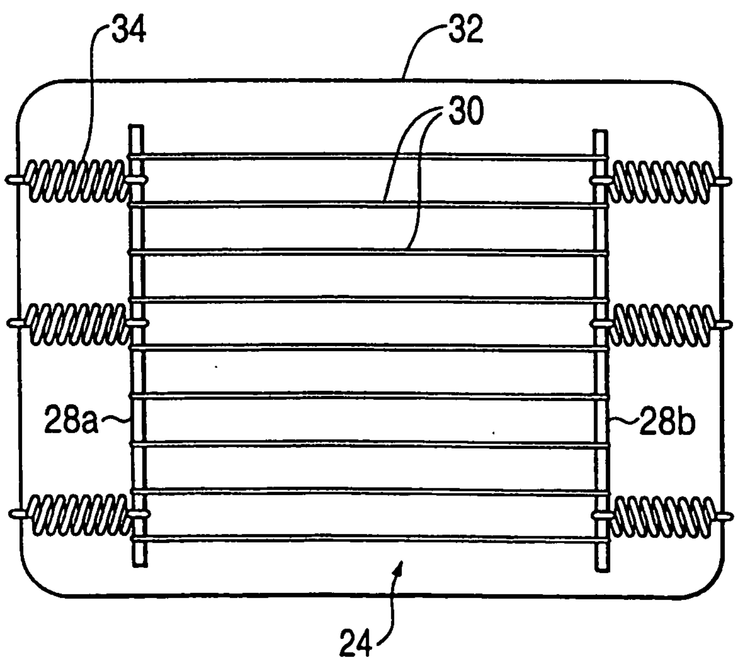
20
WEIGHT ANALYZER
22
24

FIG. 2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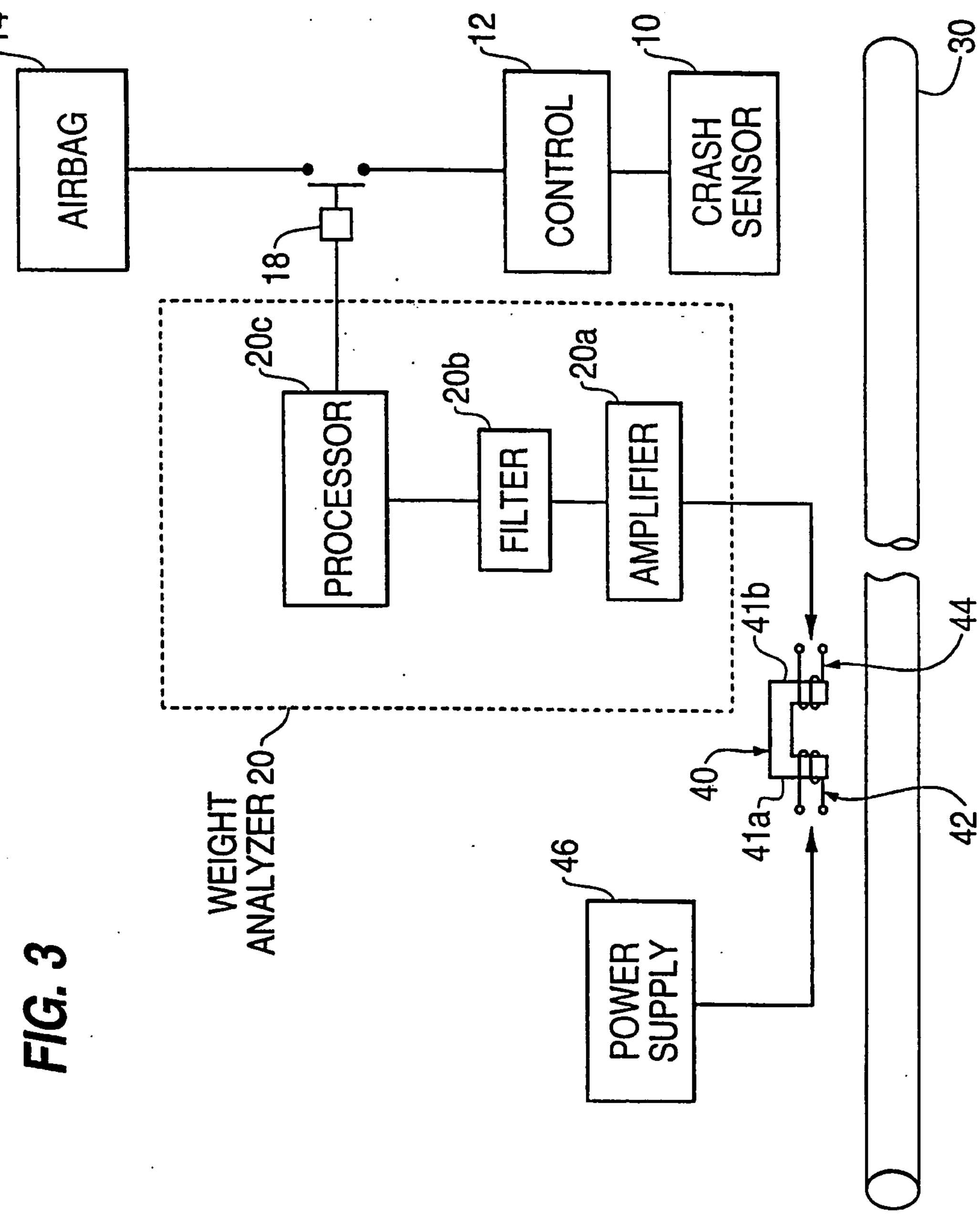
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FILTER
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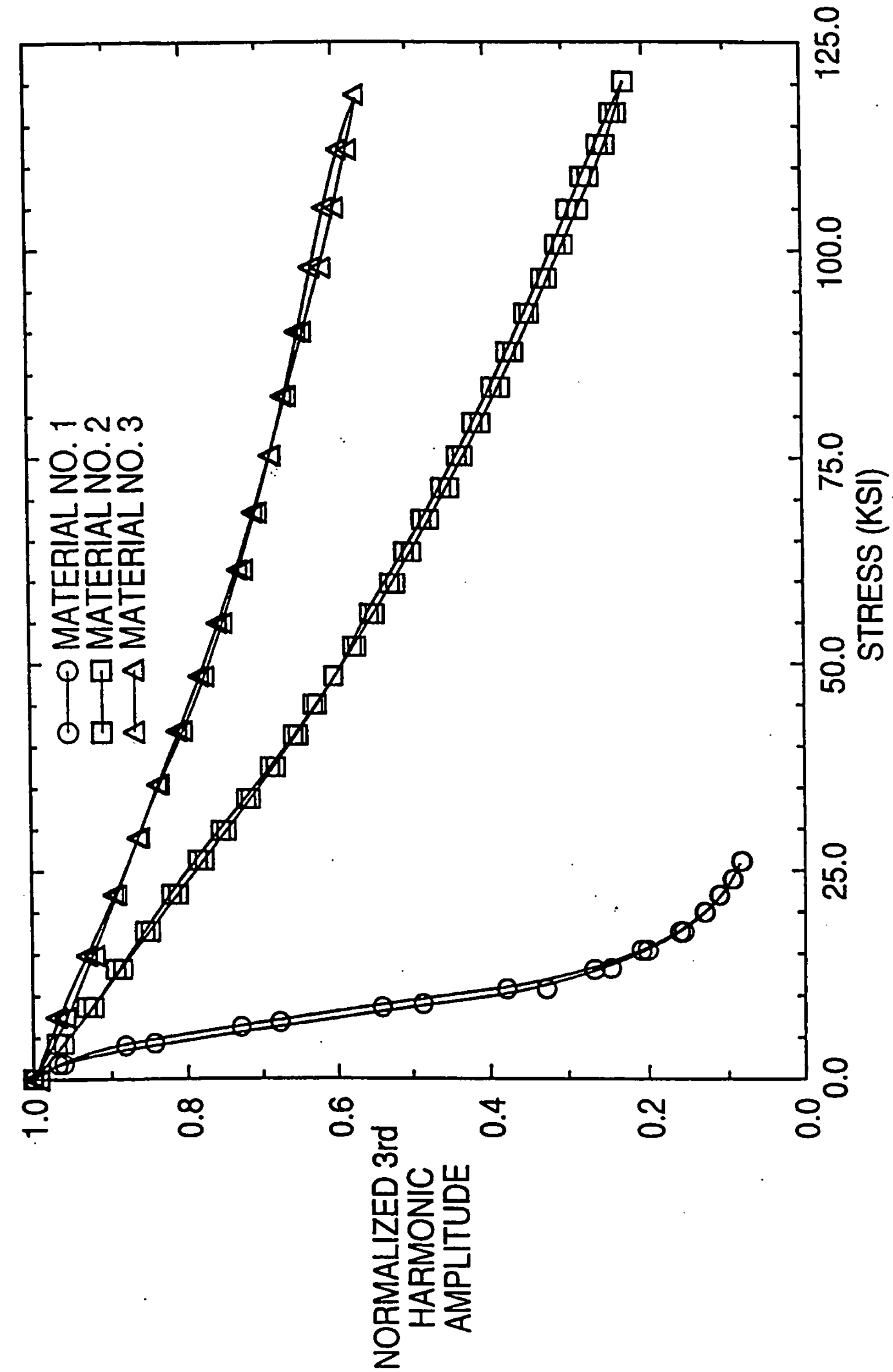
40
41a
42
POWER SUPPLY
46

FIG. 3

FIG. 4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0.0
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50.0
75.0
100.0
125.0

FIG. 5

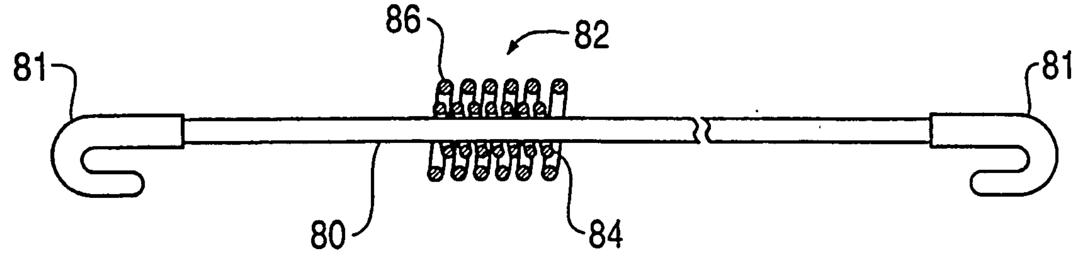
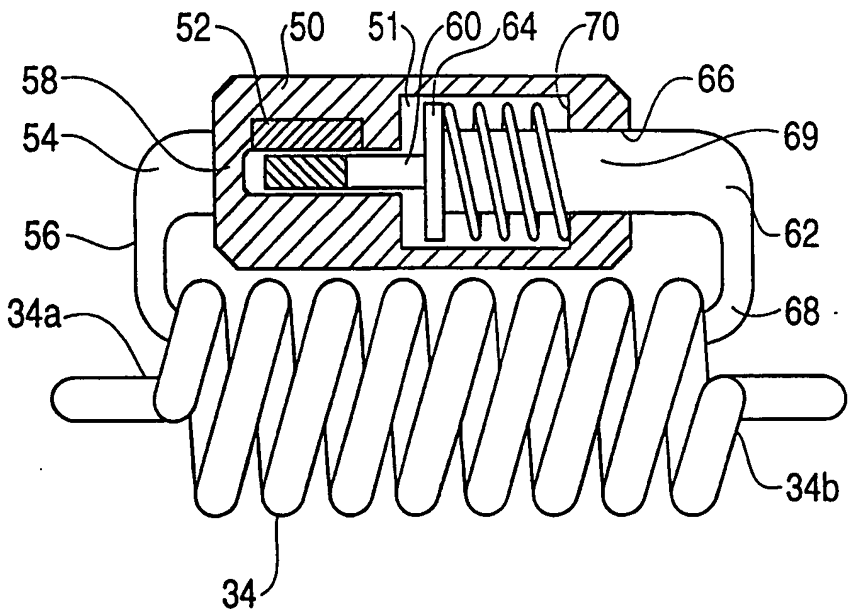


FIG. 6



INTERNATIONAL SEARCH REPORT

Inte. onal Application No
PCT/US 98/05074

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B60R21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B60R G01G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y		2-4,6

X	"METHOD FOR SENSING OCCUPANT MASS AND POSITION" RESEARCH DISCLOSURE, no. 357, 1 January 1994, page 20 XP000425349 see the whole document	1,7
Y		8,9

Y	WO 79 00369 A (STANGAKONSULT C ;JILKEN L (SE)) 28 June 1979 see the whole document	2-4
A		6

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 June 1998	12/06/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gaillard, A

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INTERNATIONAL SEARCH REPORT

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PCT/US 98/05074

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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